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TOOLS SUPPORTING COASTAL NUTRIENT CRITERIA DEVELOPMENT

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LTG 1 Poster 03

Science Questions

What are the quantitative and causal relationships between varying levels of stressors, alone and in combination, that alter aquatic ecosystem services? For nutrients?

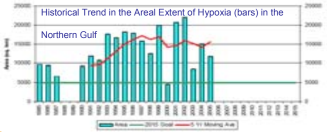
Are the Gulf of Mexico monitoring and research designs sufficiently robust to support the development of nutrient criteria and integrated modeling in the Gulf of Mexico coastal zone?

Will the results of empirical, laboratory, and modeling tools produce convergence on nutrient criteria, sufficient to accurately forecast nutrient reductions that would be protective of Gulf of Mexico coastal waters?

How Research Addresses the Water Quality MYP Goals

ORD is developing the monitoring and assessment tools and models to determine nutrient criteria for northern Gulf of Mexico coastal waters and nutrient loading targets for the Mississippi/Atchafalaya River Basin (MARB). These tools will assist federal, regional and state-based efforts to reduce watershed nutrient loads, improve MARB water quality, reduce the areal extent of hypoxic waters and restore/protect aquatic habitats and species.

In addition, information on acute sensitivity to low dissolved oxygen (DO) for life stages of commercially- and recreationally-important fish and crustaceans, and endangered fish species, will provide tools to derive DO criteria protective of these species and support nutrient criteria.



Long-term increases in watershed nutrient loading are a primary cause of extensive oxygen-depleted waters in many coastal waters, including the northern Gulf of Mexico. Nutrient criteria for the receiving water and load reduction targets for MARB will be needed to reduce hypoxia to a 5-yr running average (red line above) of 5000 km² by 2015 (green line above).

Research Objectives

Develop integrated modeling framework for the Gulf of Mexico hypoxic zone

- Integrate the physical, chemical and biological models with external nutrient loads and internal nutrient recycling processes
- Establish stressor-response relationships for nutrient loads & concentrations, chlorophyll and DO concentrations to establish nutrient thresholds/criteria
- Develop the ability to forecast benefits of nutrient load reduction options and time to realize the benefits

Support the modeling framework with seasonal field surveys and targeted research

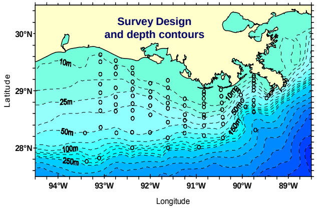
- Characterize oceanographic state variables and processes temporally (seasonal) and spatially (shelf-wide)
- Define the seaward and benthic boundary conditions for the model domain

Determine acute sensitivity to low dissolved oxygen of critical life history stages of aquatic animals

Research Methods & Collaboration

This collaborative research program involves ORD's four NHEERL Ecology Divisions and the Naval Research Laboratory in partnership with USEPA's Office of Water, Gulf of Mexico Program Office and Regions 4 & 6.

Transect stations at left were selected to characterize cross-shelf (north-south) and along-shelf (east-west) physical, chemical, and biological gradients seasonally. Vertical profiles of parameters at right are collected at each station using a CTD rosette. Sediment samples are collected with a box corer.

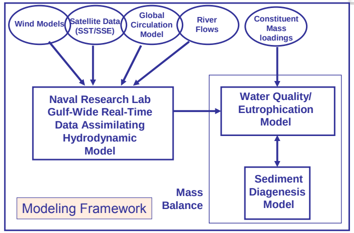


A minimum of 2 years of seasonal surveys are needed to characterize oceanographic conditions across the shelf and meet modeling needs.

Surveys Completed	Station Sampling Summary		
	CTD	CTD + Water	Benthic
Dec 2-15 2002	17	19	0
March 17-31 2003	29	36	6
June 9-23 2003	26	25	7
Nov 5-19 2003	28	42	9
April 2-7 2004	0	22	4
March 21-31 2005	24	42	10
Sept 26-Oct 9 2005	15	50	0

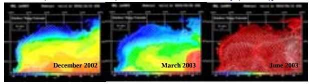
Year-one surveys were completed in 2003 aboard OSV *Peter W. Anderson*; year-two surveys will be conducted in 2006 aboard OSV *Bold*.

Parameter	Water	Sed
Dissolved Inorganic – NO_3, NO_2, PO_4, NH_4, Si	X	
Particulate C, N, P	X	X
Total Dissolved N, P, Total N, P	X	
Dissolved organic carbon	X	
Total Suspended solids	X	
Biogenic silica	X	
Chlorophyll a	X	X
PAR, secchi depth, attenuation	X	
Dissolved oxygen	X	
T, S, turbidity, transmissivity	X	
Phytoplankton taxonomy	X	
Grain size, benthic taxonomy		X
Total organic matter/organic C		X
Bulk density, porosity, % water		X
Primary productivity (^{14}C & FRRF)	X	
Bacterial productivity (^{3}H-Leucine)	X	
Respiration rates	X	
Sediment oxygen demand		X
Sulfate reduction rates		X
Benthic nutrient flux		X
Porewater Fe, sulfides, N, P		X
$\delta^{15}N$ and $\delta^{13}C$		X



Intra-Americas Sea Ocean Nowcast/Forecast System

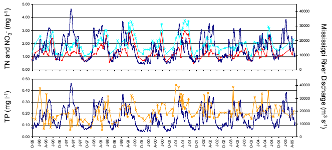
The Naval Research Laboratory's real-time model provides the data assimilating, hydrodynamic model construct for the Gulf hypoxia modeling framework [Images below show sea surface temperature (colored contours) and surface current velocity (arrows)]



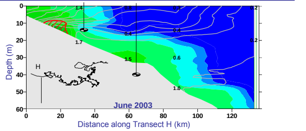
Controlled laboratory studies, using computer-controlled exposure systems, were employed to determine acute sensitivity of life history stages of aquatic animals. These data were used to derive minimum dissolved oxygen requirements of each species.

Research Results

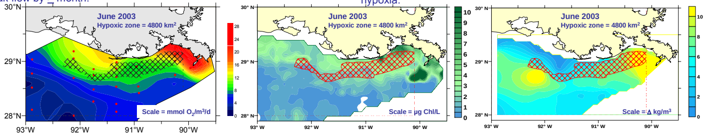
Ongoing research in the Gulf hypoxic zone is documenting the seasonal and shelf-wide distribution and variability in oceanographic conditions and processes that influence hypoxia. This synoptic monitoring effort will lead to development of a comprehensive database that supports predictive model development, calibration and validation, coastal nutrient criteria development and Interagency Hypoxia Action Plan goals.



Long-term increases in nutrient loading are a primary cause of hypoxia. Time-series of total nitrogen (TN; light blue), nitrate (red) and total phosphorus (TP; orange) - Mississippi River discharge (dark blue) is shown on both panels. Peak discharge generally occurs in the early spring. Peak TN, NO_3^-, and TP are often coincident with peak flow but in some years lags peak flow by ≥ month.



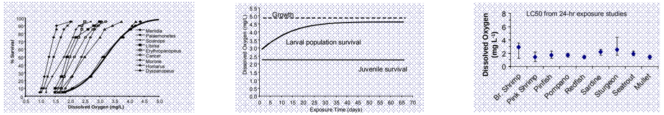
Multiple oceanographic processes influence hypoxia. The example above shows the inter-relationships among salinity structure (grey contours), hypoxic areas (red hashed area), and chlorophyll-a (µg/L; colored contours) during early summer. Euphotic zone depth, indicated by 3x secchi depth, sometimes includes the entire water column, permitting deep chlorophyll-a maxima. Modeling the optical properties of the water will be important for modeling relationships between nutrient loads and hypoxia.



Benthic-pelagic coupling of oxygen and nutrient dynamics influence hypoxia. The example above shows the spatial relationship between bottom water oxygen consumption rates (colored contours) and location of hypoxic bottom waters (hatched) during early summer.

Primary productivity and algal biomass influence oxygen dynamics and hypoxia. The example above shows surface chlorophyll-a distributions overlying hypoxic bottom waters (red cross-hatched area) during early summer.

Stratification limits water column oxygen exchange and promotes hypoxia. The example above surface to bottom water density difference (Δ σ_T) and the distribution of hypoxic bottom waters (red cross-hatched area) during early summer.



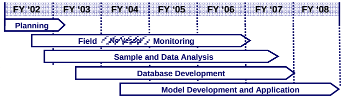
24-hr dose-response relationships for larvae of various saltwater fish and invertebrates in the Virginian Province.

Larval recruitment model developed from dose-response relationships provided a population endpoint for saltwater DO criteria.

DO requirements of juvenile/adult Gulf of Mexico fish and invertebrates provide a target for developing coastal marine nutrient and DO criteria protective of these resources.

Research Challenges & Future Directions

Modeling the development and size of hypoxia and the oceanographic processes that regulate oxygen and nutrient dynamics as a function of the timing of nutrient and organic matter loads is a challenging goal in any system, but particularly so in the northern Gulf of Mexico. Seasonal, shelf-wide monitoring is ongoing, with year-two surveys planned for 2006. Model development is underway, focusing on linking the hydrodynamic circulation model to water quality and sediment diagenesis models using data from prior surveys.



Interactions with Customers

The design and implementation of this program are the direct result of joint research and program planning efforts between ORD and its customers – OWOW, OST, GMPO, Regions, states and the Mississippi River/Gulf of Mexico Watershed Nutrients Task.

In addition, ORD is co-leading the planning of a symposium to assess the state of the science on hypoxia in the northern Gulf – the symposium is a critical element of the reassessment of the 2001 Hypoxia Action Plan being conducted by the Hypoxia Task Force.

The Gulf of Mexico Alliance – a key element of the Administration's Ocean Action Plan – has identified excessive nutrient input to coastal waters as one of the top five environmental issues of concern in the Gulf, and has developed strategic objectives to reduce nutrient loadings across the Gulf. ORD's efforts are identified as critical to achieving these objectives, and continued communication with the Gulf Alliance will ensure that the tools developed will meet customer needs.

How Research Contributes to Outcomes

The tools developed from this research –

- monitoring approaches & methodologies
- comprehensive QA/QC'ed database
- simulation/predictive models with known uncertainties -

will be used by OWOW, OST, Regions, states and the Hypoxia Task Force to guide nutrient management programs in the nearshore coastal waters of the northern Gulf coastal zone and upstream into watersheds of the Mississippi River Basin.